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BIOPHYSICS.—*The living plant as a physical system.*[1] LYMAN J. BRIGGS, Bureau of Plant Industry.

In early investigations relating to the growth of plants, the conception of a so-called "vital force" was frequently employed in the interpretation of the observed phenomena. It was long held, for example, that the organic substances found in plants and animals were dependent in their formation upon the existence of vital forces, and that in consequence such products could not be produced in the laboratory. The classical discovery of Wöhler that urea could be synthesized in the laboratory revolutionized the conception that *all* animal and plant products are dependent upon some vital force for their production. Since that time many other organic substances found in or derived from plants have been prepared synthetically. Many other phenomena associated with plant growth and formerly attributed to the existence of some peculiar vital force have through modern methods of investigation been satisfactorily explained from physico-chemical considerations. Until matter in that state which we term "living" can be synthesized, the doctrine of vitalism can scarcely be said to have been disproved; but it is surely being restricted more and more as our knowledge of plant phenomena increases. The situation at present may perhaps be fairly summarized as follows: The mechanism of plant processes

[1] Address of the retiring President of the Philosophical Society of Washington, presented before the Society January 19, 1917.

not at present explainable on a physico-chemical basis would be termed by the vitalistic school as "vital;" by the physico-chemical school, "unknown."

*The efficiency of plant systems.* I shall ask you in what follows to consider the plant from the point of view of a physical system, a system which is absorbing energy and performing useful work. Radiant energy is absorbed by this system from the sun and sky, and under some conditions heat is absorbed from the surrounding air as well. This energy is used to do work upon water and nutrients taken in through the roots and upon carbon dioxide absorbed through the leaves. A part of the energy, through the agency of remarkable catalyzing substances—the chlorophyll bodies and the protoplasm—is employed in the transformation of the materials absorbed into plant tissue. The latter represents the useful work performed by the system, which may be quantitatively determined by measuring the heat of combustion of the total plant substance formed. The remainder of the absorbed energy is spent in lifting and vaporizing water, except in those cases where the temperature of the plant rises above that of the surrounding air. In such instances heat energy is also transferred to the air.

Let us for the present assume that the temperature of the plant does not exceed that of the air, an assumption which leaf temperature measurements have shown to be amply justified in the case of actively growing plants in a dry atmosphere. The total energy used by the system in a given time will then be represented by the total heat equivalent of the water evaporated, plus the total heat of combustion of the plant substance developed during this period. If we represent the former by $Q_e$ and the latter $Q_c$, both expressed in gram-calories, the efficiency ($E$) of the system may be represented by the relation

$$E = \frac{Q_c}{Q_e + Q_c} \tag{1}$$

Both quantities are capable of direct measurement. The water evaporated can be determined by means of suitably controlled field experiments designed to prevent all loss of water

except that taking place through the leaves, while the heat of combustion may be found by finally burning in a bomb calorimeter a representative sample of the plant substance produced.

Numerous investigations have been made of the water requirement of plants, i.e., the ratio of the weight of water absorbed by the plant during its growth period to the weight of dry matter produced. It will accordingly be convenient to transform our efficiency equation to include this term. If a mass $M_w$ of water is transpired in the production of a mass $M_p$ of plant tissue, and if $h_v$ and $h_c$ represent the heat of vaporization of water and the heat of combustion per gram of plant substance respectively, then

$$Q_v = M_w h_v \tag{2}$$

$$Q_c = M_p h_c \tag{3}$$

Substituting these quantities in equation (1) and remembering that $M_w/M_p$ is by definition the water requirement $R_w$, we have

$$E = \frac{1}{\frac{h_v}{h_c} R_w + 1} \tag{4}$$

Determinations of the heat of combustion of the dry matter of various plants do not appear to have been made. In the absence of more specific data, we may assume the heat of combustion to be represented approximately by that of cellulose, namely, 4200 gram-calories per gram. By substituting this value together with that of the heat of vaporization of water (536 gram-calories per gram) in equation (4) we have as a first approximation to the efficiency of the plant system

$$E = \frac{1}{0.13\, R_w + 1} \tag{5}$$

The water requirement of field crops in the Great Plains as measured by Dr. H. L. Shantz and the writer ranges from 200 to 1000, depending upon the species and the evaporation-rate.[2]

[2] BRIGGS, L. J., and SHANTZ, H. L. *Relative water requirement of plants.* Journ. Agr. Research, **3**: 1–63. 1914.

The lowest water requirement so far observed in the case of a field crop was obtained at Arlington, Virginia, in 1915, where corn and sorghum gave values of 151 ± 2 and 150 ± 2 respectively. If we substitute these values in equation (5) we find that the efficiency of the plants with the lowest water requirement so far measured is only about 5 per cent, while in the case of plants with a water requirement of 1000, the efficiency is less than 1 per cent. In other words, the fuel value of the plant, i.e., the potential energy stored in the plant substance, represents only from 1 to 5 per cent of the energy dissipated during the growth of the plant.

Since the efficiency is approximately inversely proportional to the water requirement it is of interest to consider briefly how the latter may be reduced. Two procedures are open, namely, plant selection and reduction in the evaporation rate. Different species of plants under the same environment show wide differences in water requirement. For example, Shantz and the writer have found the water requirement of alfalfa to be approximately three times that of millet, when the two species are grown in large pots side by side. It is thus evident that in a region where the rainfall is the limiting factor in plant production, the fuel value of the plant material produced will vary widely according to the water requirement of the plant. It would be of much interest in this connection to know something of the efficiency of different forest trees, but no water requirement measurements of such plants are yet available.

The second means of reducing the water requirement consists in the selection of habitats where the evaporation-rate is low. Here again little is known quantitatively as to what extent the efficiency may be increased in this way, and the subject affords a wide field for exploration. It is evident that if the absorption of water from the soil is so far reduced by increasing the humidity that the plant receives an inadequate supply of nutrients from the soil, growth would be retarded from this cause. Again, if we reduce the energy dissipated in evaporation by shading the plants, a limit will be set by the minimum quantity of radiant energy necessary for the photosynthetic processes.

*The growth-rate.* We pass now to the consideration of our plant system from the standpoint of the growth-rate. The plant system is remarkable in that the useful work done is expended in increasing the size of the system, at least during the earlier stages of growth. Furthermore, the quantity of catalyzer available for transforming the absorbed substances also increases with the size of the system. Therefore, while the efficiency of the system may not change during the growth of the plant, the quantity of useful work which it is capable of doing may theoretically increase at a rate proportional to the size of the system, assuming that an adequate supply of the products used in synthesis, i.e., carbon-dioxide, water, and nutrients from the soil, are present. This hypothesis is equivalent to saying that the rate of change of the weight $m$ of the plant system is proportional to the weight itself, or, put into mathematical form:

$$\frac{dm}{dt} = a_1 m \tag{6}$$

Let us now see how nearly this assumption may be realized in nature.

Since it is not possible to determine directly the dry weight $m$ without destroying the plant, we must have recourse to some indirect means of determining the mass of material present at any time. We shall, therefore, make a further assumption that the increase in size of the plant from day to day is accompanied by a corresponding increase in the quantity of water which it transpires, a quantity which as we have seen is readily measured. This latter quantity, however, would obviously depend upon the weather of each day, so that we must either maintain the plant under constant conditions from day to day during the course of the experiment, or we must correct the transpiration in accordance with the intensity of the weather factors each day. The latter procedure is the one which we have actually employed. This correction may be made in a simple manner by dividing the observed transpiration during a day by the observed evaporation from a shallow blackened tank for the corresponding day. This gives us a series of numbers which are proportional

to the transpiration or water loss from the plant during a series of uniform days, providing transpiration and evaporation are influenced in the same way by the changes in the weather. Our problem then is to determine how the transpiration corrected to the basis of uniform days varies with the time, our assumption being that the daily transpiration is dependent upon and is a measure of the size of the plant.

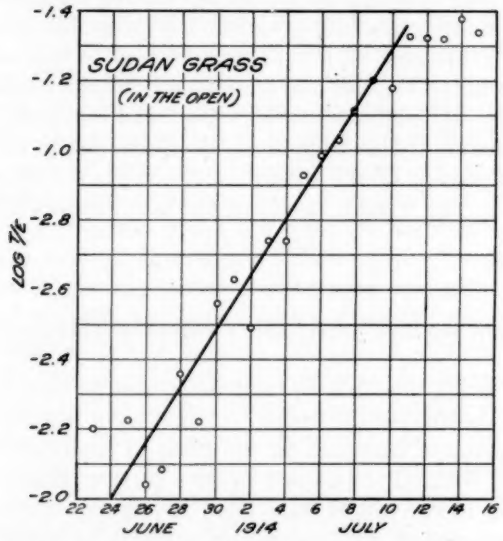


Fig. 1. Graph showing linear relationship between the logarithm of the transpiration-evaporation ratio of Sudan grass and the time. After Briggs and Shantz.

If now we return to our original hypothesis, that the rate of change in the size of the plant is proportional to the size of the plant itself, we will have by substituting the transpiration-evaporation ratio $\frac{T}{E} = k$ for the weight $m$ of the plant in our original equation (6)

$$\frac{dk}{dt} = a_1 k \qquad (6a)$$

Integrating this equation and transforming to common logarithms, we have

$$\log_{10} k = at + c \tag{7}$$

in which $c$ is the logarithm of $k$ when $t = 0$, that is at the be-

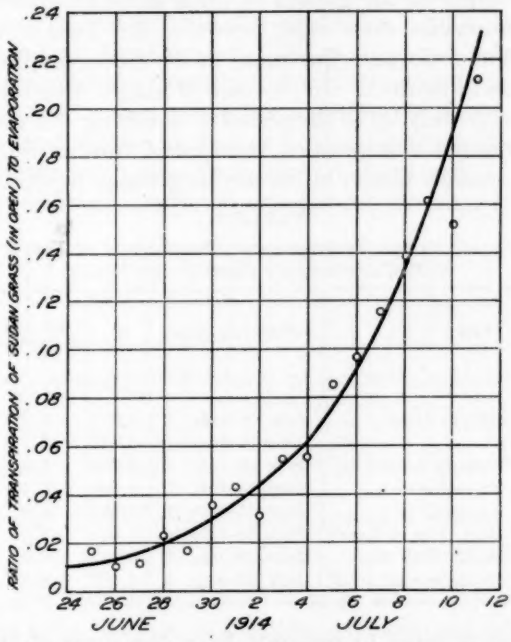


Fig. 2. Daily change in the ratio of transpiration to evaporation during early growth of Sudan grass. Circles represent observed ratios. Solid line computed from relationship in figure 1. After Briggs and Shantz.

ginning of the period under discussion. Expressing (7) exponentially, we have

$$k = 10^{at+c} = k_0 \cdot 10^{at} \tag{8}$$

Therefore, if the logarithms of the daily transpiration-evaporation ratio, when plotted against the time, form a straight line, the condition expressed in equation (6*a*) is satisfied, and the

plant increases in size in accordance with the compound interest law.

This method has been employed by Shantz and the writer in the examination of the daily transpiration of Sudan grass, corn, sorghum, and alfalfa.[3] The results indicate that during the early stages of the growth of these crops an approximately linear relationship does exist between the logarithm of the transpiration ratio and the time, as is shown in the case of Sudan grass in figure 1. In the case of alfalfa, this relationship held approximately up to the period of flowering. A comparison of the computed transpiration ratio (solid line) of Sudan grass with that actually observed (circles) is given in figure 2.

TABLE 1

RATE OF INCREASE IN THE TRANSPIRATION COEFFICIENT OF DIFFERENT CROPS IN 1914, ACCORDING TO BRIGGS AND SHANTZ

| CROP | OBSERVATION PERIOD | (a) | DAILY RATE OF INCREASE | DAYS REQUIRED FOR $k$ TO DOUBLE IN VALUE |
|---|---|---|---|---|
| | | | *per cent* | |
| Corn, Northwestern Dent | June 18–July 9 | 0.026 | 6.2 | 11.6 |
| Corn, Algeria | June 18–July 11 | 0.044 | 10.7 | 6.8 |
| Sorghum, Minnesota Amber | June 18–July 9 | 0.041 | 9.9 | 7.3 |
| Sudan grass (in inclosure) | June 18–July 10 | 0.066 | 16.4 | 4.6 |
| Sudan grass (in open) | June 24–July 11 | 0.082 | 20.8 | 3.7 |
| Alfalfa, E23 (first crop in open) | June 16–July 10 | 0.033 | 7.9 | 9.1 |
| Alfalfa, E23–20–52 (first crop) | June 19–July 9 | 0.037 | 8.9 | 8.1 |
| Alfalfa, E23–20–52 (second crop) | July 18–Aug. 5 | 0.037 | 8.9 | 8.1 |

It is also possible to compute from the slope of the graphs the value of the exponent $a$ in equation (8) and so to determine the daily rate of increase in the size of the plant. The results of such calculations for a number of plants are given in table 1. It will be seen that in the case of Sudan grass the plant system was doubling in size every four days, and in the case of alfalfa about every eight days.

Therefore during the early stages of growth the size of some of

[3] BRIGGS, L. J., and SHANTZ, H. L. *Daily transpiration during the normal growth period, and its correlation with the weather.* Journ. Agr. Research, 7: 155–212. 1916.

our common plants varies as an exponential function of the time, in so far at least as such changes in size are reflected by the change in transpiration through a series of uniform days. In other words the young plant confronted with the problem of maturing its seed and completing its life cycle before the advent of frost, proceeds to develop its system at the maximum possible rate consistent with the conditions, i.e., in accordance with the compound interest law. When an adequate leaf system is secured, the plant apparently turns its attention to the elaboration of material for seed production and the rate of increase in the size of the leaf system is modified. It is evident that any inhibiting factor, such as a limitation in the supply of water or of nutrient solution also would bring about the same result.

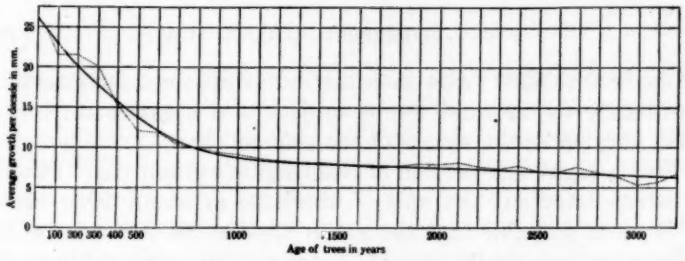


Fig. 3. Change in thickness of annual rings of Sequoia with the time. After Huntington.

Let us now turn from annual plants, which complete their life cycle in a few months, to the other extreme, and examine the rate of growth of the giants of the plant world, the Sequoias or big trees of California. Huntington[4] has recently made extensive measurements of the thickness of the annular rings of these trees with a view to determining to what extent the variation in thickness of these rings is correlated with fluctuations in the weather conditions during the life of the tree. His measurements showing the change in thickness of the ring as the tree grows older, based upon measurements of trees of varying ages up to

[4] HUNTINGTON, E. *The climatic factor as illustrated in arid America.* Carnegie Inst. of Washington, Pub. No. 192. 1914.

3200 years, are summarized graphically in figure 3. The dotted line in this figure connects the 100-year means, through which a smoothed graph has been drawn. If we assume the latter to represent the relation between the thickness of the rings and the age of the tree, we see that after the trees have reached an age of about 1200 years, the ring thickness $\frac{dr}{dt}$ is a linear function of the time, or

$$\frac{dr}{dt} = -at + b \tag{9}$$

Integrating this equation and evaluating the constants from figure 3, we have as the relation between the stump radius of the tree in millimeters and the time in years, starting with trees 1200 years old,

$$r = -0.00005t^2 + 0.83t + 1670 \tag{10}$$

From 1200 to 3200 years then the radius does not increase proportionally to the time, but is subject to a negative correction term varying as the square of the elapsed time.

The straight line portion of Huntington's graph (fig. 3) would if extrapolated cut the axis of abscissae at about 9000 years. It is more probable that the graph approaches the axis of abscissae asymptotically, since the straight line relationship would lead to a shrinkage after 9000 years. The relationship expressed in equation (*10*) must therefore be restricted practically to the period covered by the observations.

It is perhaps of more interest to consider the rate of growth of these old trees. In this connection let us determine how the tree would increase in diameter if a uniform quantity of woody tissue were laid down each year. We may for this purpose assume the stem of the tree to have the form of a right cone with a base radius $r$ and height $h$, and we will also assume that the height of the cone increases in proportion to the radius. We may then look upon the growth each year as consisting of a thin layer or shell of thickness $dr$ wrapped closely about the cone.

The volume $V$ of the trunk of this idealized tree at any time would be

$$V = \tfrac{1}{3}\pi r^2 h \tag{11}$$

or, since by assumption $h = \alpha r$

$$V = \tfrac{1}{3}\pi\alpha r^3 \tag{12}$$

The rate of growth would be

$$\frac{dV}{dt} = \pi\alpha r^2 \frac{dr}{dt} \tag{13}$$

hence the necessary condition for a uniform growth rate is that

$$\frac{dt}{dr} = cr^2 \tag{14}$$

where $c$ is a constant.

Let us now examine Huntington's data for the Sequoia by plotting $\frac{dt}{dr}$ against $r^2$. If a portion of the resulting graph is a straight line, the growth-rate during the corresponding period will be constant, subject of course to the assumption made regarding the form of the tree. This graph is presented in figure 4. It will be seen that the growth-rate decreases for values of $r^2$ up to 30,000 cm$^2$, corresponding to trees about 1200 years of age. For values greater than this, however, the relationship is approximately linear, i.e., the growth-rate is constant within the errors of the determinations. The oldest trees included in these measurements were over 3000 years of age. Since the birth of Christ, therefore, these giant trees have been growing at a practically uniform rate, save as that rate has been modified by weather conditions.

*Gas exchange between the leaf and the air.* We pass now to a consideration of some of the physical processes within the plant. We shall first consider the path by which carbon dioxide enters the leaf. The rate of assimilation of carbon-dioxide by an active leaf in bright sunlight is very great. In fact Brown and Escombe have found that a Catalpa leaf in bright sunshine will absorb carbon-dioxide at a rate one-half as fast as it would if the lower surface of the leaf were covered with a film of caustic potash solution constantly renewed. The stomatal openings in the

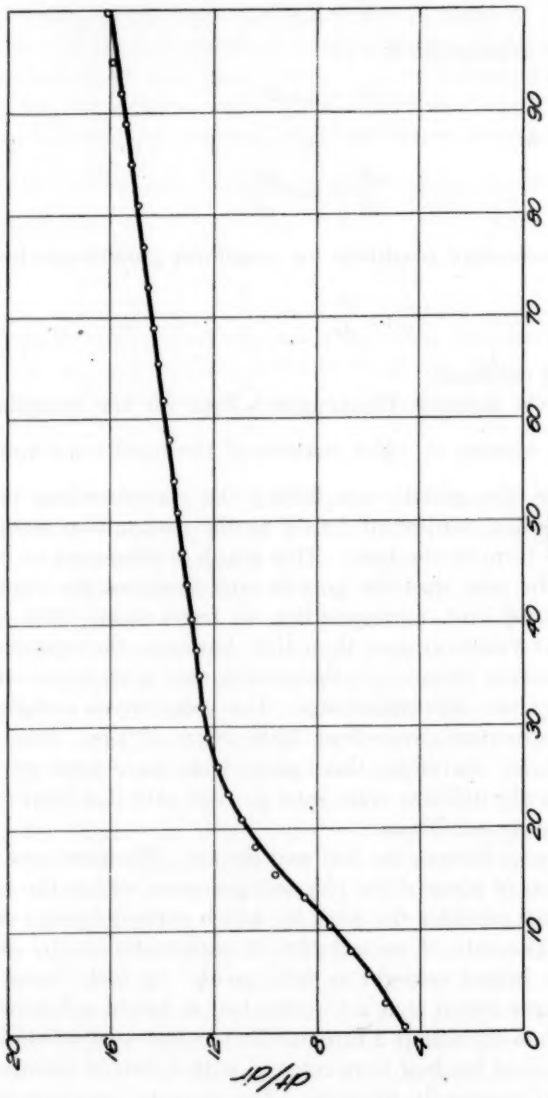


Fig. 4. Graph showing linear relationship between the square of the radius of old Sequoia trees and the reciprocal of the ring thickness, thus indicating a constant growth-rate during the corresponding period.

leaf are extremely minute and their total area is only about 1 per cent of the leaf area. How does the carbon-dioxide enter the leaf? Does the interchange of gas and water vapor between the leaves and the air take place by means of diffusion through the cuticle of the leaf? Or do the minute stomatal openings provide the means of entrance and exit?

The early experiments of Boussingault,[5] in which the rate of assimilation of carbon-dioxide by leaves having their stomata blocked with lard was compared with that of normal leaves, led to the conclusion that the absorption of carbon-dioxide by the leaf takes place by means of cuticular diffusion, and that the stomata play little or no part in the process. The cuticular diffusion hypothesis found favor also on account of the relatively large surface available for diffusion compared with the area of the stomatal openings.

Boussingault's experiments, however, were carried out in an atmosphere abnormally high in carbon dioxide, and in 1895, Blackman[6] showed that the relative amount of carbon dioxide assimilated by leaves with stomata blocked and free was dependent upon the carbon dioxide content of the air. When the carbon dioxide content was reduced to partial pressures corresponding more nearly with atmospheric conditions, an Oleander leaf with its stomata blocked showed a much lower assimilation of carbon dioxide than a similar leaf with open stomata. In other words, the high partial pressure of carbon dioxide in Boussingault's experiments resulted in a carbon dioxide poisoning of the leaf having open stomata, and a corresponding reduction in assimilation; whereas, in the case of the leaf with its stomata blocked, sufficient protection was afforded to permit assimilation to proceed normally. Blackman concluded that for partial pressures of carbon dioxide approaching that in the atmosphere, no appreciable diffusion through the cuticle of the leaf takes place.

[5] BOUSSINGAULT, M. *Étude sur les fonctions des feuilles.* Agronomie, Chemie Agricole et Physiologie, **4**: 267–401. 1868.

[6] BLACKMAN, F. F. *On the paths of gaseous exchange between aerial leaves and the atmosphere.* Phil. Trans., **186B**: 508–562. 1895.

Living plants in the dark slowly give off carbon dioxide as a respiration product, similar to animals. Blackman made use of this phenomenon in a further investigation of the function of the stomata. Two constant currents of air free from carbon dioxide were passed through capsules clamped to the leaf and made tight with wax seals, and the amount of carbon dioxide given up by the leaf determined. A summary of some of Blackman's measurements is presented in table 2. The first three plants are evergreens with a thick cuticle. The leaves of the other plants investigated are thin, and those of *Polygonum*, in particular, are extremely delicate. In all cases the stomata are

TABLE 2

RESPIRATION OF $CO_2$ IN CUBIC CENTIMETERS PER HOUR FROM UPPER AND LOWER SURFACES OF LEAVES HAVING STOMATA CONFINED TO LOWER SURFACES, ACCORDING TO BLACKMAN

| PLANT | DEVELOPING LEAVES | | | MATURE LEAVES | | |
|---|---|---|---|---|---|---|
| | Upper surface | Lower surface | Ratio | Upper surface | Lower surface | Ratio |
| *Nerium oleander* | 0.001 | 0.147 | $\frac{1}{100}$ | 0.002 | 0.078 | $\frac{2}{100}$ |
| *Prunus laurocerasus* | 0.001 | 0.085 | $\frac{1}{100}$ | 0.002 | 0.076 | $\frac{2}{100}$ |
| *Hedera helix* | 0.001 | 0.075 | $\frac{1}{100}$ | 0.002 | 0.054 | $\frac{4}{100}$ |
| *Platanus occidentalis* | | | | 0.001 | 0.05 | $\frac{2}{100}$ |
| *Ampelopsis hederacea* | | | | 0.003 | 0.10 | $\frac{3}{100}$ |
| *Polygonum sacchalinense* | | | | 0.002 | 0.03 | $\frac{6}{100}$ |

confined to the under side of the leaf. Reference to the table will show that the respiration is confined almost wholly to the stomatal side of the leaf, the maximum respiration from the upper side being only 6 per cent of that from the lower and in most instances far less than this.

This capsule method was also employed by Blackman for investigating the relative rate of absorption of carbon dioxide by the two sides of the leaf. Air containing a known amount of carbon dioxide was passed through capsules provided with glass faces, the surface of the leaves being brightly illuminated. The air after traversing the capsules was analyzed for carbon dioxide. In this way, Blackman found that in the case of leaves

having their stomata all on the under side no carbon dioxide, was taken up by the upper surface of the leaf even in direct sunshine. On the other hand, in the case of leaves with stomata on both sides, both the upper and the under side of the leaf were active in assimilation.

We have seen that according to Brown and Escombe, absorption of carbon dioxide by the under side of the Catalpa leaf proceeds about one-half as rapidly as it would if the leaf surface were covered with a constantly renewed film of caustic soda. If, then, the absorption of carbon dioxide takes place only through the stomata, the total area of which when fully opened is only

TABLE 3

DIFFUSION OF CARBON DIOXIDE THROUGH CIRCULAR APERTURES OF DIFFERENT DIAMETERS, ACCORDING TO BROWN AND ESCOMBE

| NO. | DIAMETER OF APERTURE | $CO_2$ DIFFUSED PER HOUR | RATIO OF AREAS OF APERTURES | RATIO OF DIAMETERS OF APERTURES | RATIO OF $CO_2$ DIFFUSED IN UNIT TIME |
|---|---|---|---|---|---|
| | *mm.* | *cc.* | | | |
| (1) | 22.70 | 0.23800 | 1.00 | 1.00 | 1.00 |
| (2) | 12.06 | 0.09280 | 0.28 | 0.53 | 0.39 |
| (3) | 12.06 | 0.10180 | 0.28 | 0.53 | 0.42 |
| (4) | 5.86 | 0.05558 | 0.066 | 0.25 | 0.23 |
| (5) | 6.03 | 0.06252 | 0.07 | 0.26 | 0.26 |
| (6) | 3.23 | 0.03988 | 0.023 | 0.14 | 0.16 |
| (7) | 3.22 | 0.03971 | 0.020 | 0.14 | 0.16 |
| (8) | 2.00 | 0.02397 | 0.007 | 0.088 | 0.10 |
| (9) | 2.12 | 0.02608 | 0.008 | 0.093 | 0.10 |

about 0.9 per cent of the area of the under side of the leaf, the rate of diffusion per unit area through these openings must be approximately 50 times the rate at which carbon dioxide is absorbed per unit area by a caustic soda solution of the same total area as the leaf.

*Diffusion through perforate septa.* It will at once be noted that the two systems just compared differ in one important respect. The absorbing surface presented by caustic soda solution is in the form of a single continuous surface. The stomatal system on the other hand is made up of minute elliptical openings separated by intervals from 5 to 10 times the diameter of the

stomata. Is the diffusion-rate through a multi-perforate septum of this kind sufficient to account for the rate at which carbon dioxide is absorbed by the leaf?

This problem was made the subject of an extensive investigation by Brown and Escombe[7] in 1900. The diffusion of carbon dioxide in cylinders partially filled wih caustic soda solutions was first studied. When such cylinders were exposed in still air it was found, as might be expected, that the amount of carbon dioxide diffusing down the cylinders in a given time varied directly as the cross-sectional area of the cylinders and inversely as their length. If, however, the diffusing tubes were partially closed at the top by septa with single circular openings of different diameters, the diffusion was found to be proportional, not to the areas of the apertures, but approximately to their radii. In other words, the diffusion through small isolated circular openings proceeds much more rapidly than would be indicated by the area of the opening. Some of the results obtained by Brown and Escombe, from which they developed the so-called diameter law controlling stomatal diffusion, are given in table 3.

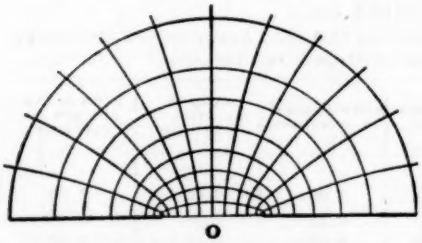


Fig. 5. Diffusion of carbon dioxide into a stomatal opening of a leaf surrounded by still air. The surfaces representing uniform partial pressures of $CO_2$ are ellipsoids, which are cut at right angles by the diffusion stream lines (hyperbolas). After Brown and Escombe.

Brown and Escombe call attention to the analogy between the diffusion system which they investigated and that of an electrified disk. The electrostatic capacity of such a disk may be shown from theoretical considerations to be proportional, not to the area of the disk, but to its diameter. The equipotential surfaces about such a disk (fig. 5) are ellipsoids having the edges

[7] BROWN, H. T., and ESCOMBE, F. *Static diffusion of gases and liquids in relation to the assimilation of carbon and translocation in plants.* Phil. Trans., 193B: 223–291. 1900.

of the disk as foci; while the lines of force along which an electrified particle would move to the disk lie in the surfaces of hyperboloids which cut the ellipsoids at right angles and have their foci in the edges of the disk.

Consider the electrified disk to be replaced by a liquid film which absorbs carbon-dioxide perfectly and which is surrounded by still air. The ellipsoidal shells now become surfaces representing uniform concentrations of carbon-dioxide, and the hyperboloidal shells represent surfaces along which the carbon-dioxide molecules are streaming to the disk. It is evident that the rate of diffusion through the absorbing surface is far greater than for an equal area in free space; and if the electrostatic analogy holds, the diffusion in unit time would be proportional to the diameter of the disk, which is in accord with Brown and Escombe's results.

We pass now to the consideration of multi-perforate septa. It is evident that if the small openings through the septum were sufficiently close together, one aperture would modify the stream lines through another, and the diameter law would not hold. This matter was experimentally investigated by Brown and Escombe, using septa perforated with holes 0.38 mm. in diameter. They concluded that when the distance between the apertures is not less than ten times the diameter of an aperture, there is no interference in the diffusion through neighboring holes.

It remains to be seen how closely the rate of diffusion of carbon-dioxide into the leaf of a plant may be calculated from the diameter law, when the size and number of the stomatal openings are known. Such calculations as a matter of fact lead to values very much in excess of the actual quantity of carbon-dioxide taken in by a leaf, even when it is assimilating most actively. The maximum assimilation of carbon-dioxide by sunflower so far recorded amounts to only 5 to 6 per cent of the possible assimilation according to theory. This lack of agreement is ascribed by Brown and Escombe to the fact that the cells in the stomatal cavity are not perfect absorbers of carbon-dioxide; in other words that the partial pressure of carbon-dioxide at the surface of these cells is not reduced to zero as assumed in the

theoretical deductions. This explanation is not altogether satisfying and leads to the query whether the diameter law holds when extrapolated to the degree necessary to apply to the stomatal system. The smallest apertures used in the development of the diameter relationship was about 2 mm., whereas the diameter of the stomatal openings is of the order of 0.01 mm.

The rate of diffusion of water vapor outward through the stomatal opening affords a possible method for checking Brown and Escombe's deductions, which they do not appear to have employed. By observing the diffusion-rate of water vapor instead of carbon-dioxide the assumption regarding the imperfect absorption of carbon-dioxide would be avoided. The determination of the vapor pressure in the interior of the leaf would be necessary, but this could be made with a fair degree of accuracy by measuring the temperature of the leaf and the concentration of the cell contents.

It is of interest to consider in this connection the work of Buckingham[8] on the diffusion of carbon-dioxide through soils. He found experimentally that the rate of diffusion varied as the square of the porosity, the latter term denoting the volume of the interstitial space between the soil grains unoccupied by water, expressed in per cent of the total volume. He also tested this observed relationship by assuming all the soil grains to be removed, so that the porosity would be 100 per cent. This should lead to the velocity of free diffusion of carbon-dioxide in air, and Buckingham's empirical equation gave a result well in accord with previous determinations of free diffusion by other investigators. It will at once appear that this deduction departs widely from the diameter law of Brown and Escombe. If we consider a volume of soil of unit thickness, the porosity will be proportional to the integrated area of the interstitial spaces in any plane parallel to the surface. If we assume as a first approximation that the pores are uniform in cross-section, then the porosity would be equal to the product of the number of pores $n$ and the cross-section $a$, or the diffusion

[8] BUCKINGHAM, E. *Contributions to our knowledge of the aeration of soils.* U. S. Dept. Agr., Bur. Soils Bulletin No. 25. 1904.

would be proportional to $n^2a^2$. According to Brown and Escombe the diffusion would be proportional to $n\sqrt{a}$. While it is evident that in this comparison we are not fulfilling one important condition imposed by Brown and Escombe, namely, that the pores shall be sufficiently far apart to avoid interference in the diffusion stream lines, the two conclusions are at such great variance as to invite a further examination of the diameter law.

*The ascent of sap.* We have to consider finally the means by which the water is lifted to the tops of the highest trees, amounting in the case of the Sequoia to a distance of 300 feet above the ground.

Strasburger,[9] by poisoning the cells of various plants, has shown that the living elements of the wood play no essential part in the elevation of the water. An oak nearly 22 meters high cut off obliquely at its base and set in a picric acid solution was found to take up the poisonous solution readily. After the acid had reached a height of 15 meters and the topmost leaves had changed markedly in appearance, fuchsin was added to the picric acid solution. At the end of nine days the highest branches were found to be impregnated with picric acid, which had been drawn up to a height of nearly 22 meters. Fuchsin also was found in these branches, although preceded by the picric acid by three days. This experiment, then, demonstrated that water solutions can rise in trees without the assistance of living cells to heights far above those that can be accounted for by atmospheric pressure. Strasburger also found that stems of plants killed by subjecting them to a temperature of 90°C. were still capable of raising water to a height of 10.5 meters. We may, therefore, conclude that vital processes are not essential to the ascent of sap.

Of the numerous theories which have been advanced in explanation of this phenomenon, that of Dixon and Joly[10] alone appears to be physically sound. According to these authors, sap rises through the trunk of the tree as the result of evapora-

[9] STRASBURGER, E. *Ueber das Saftsteigen.* Histol. Beitr., **5**: 10. 1893.

[10] DIXON, H. H., and JOLY, J. *On the ascent of sap.* Phil. Trans., **186B**: 563–576. 1895.

tion from cells communicating with the stomatal cavities of the leaf. The column is then, so to speak, hung from these leaf cells, and is supported by the adhesion of the water to the walls of these cells. We may consider the outer surfaces of these cells to be saturated with water, which retreats into the wall tissue in such a way as to form a great number of capillary surfaces of high curvature, this curvature in fact being such as would be necessary to support a capillary column of the observed height. If through the evaporation of water from the leaves the curvature tends to increase, the force exerted by these curved surfaces will increase proportionally, and additional water will be drawn from the soil, tending to restore the equilibrium.

It will at once be evident that this conception postulates that water must have great cohesion, sufficient in fact to withstand the weight of a column 300 feet or more in height. Since this is an essential condition of the theory, we may profitably consider the cohesion of water in more detail.

Berthelot[11] in 1850 showed that a column of water under suitable conditions can withstand a very great tensile stress. A strong capillary tube sealed at one end and drawn to a fine point at the other was filled with water at a temperature of 30°. The water was then cooled to 18° and the tube allowed to draw in air, after which the tube was sealed. The tube was now heated to 30° and the contained air was forced into solution, so that the water occupied the entire volume of the tube. On again cooling the tube to 18° it was found that the liquid continued to occupy the entire volume of the tube. To produce a compression equal to this observed dilatation would require a pressure of about 50 atmospheres, from which Berthelot concluded that a water column is capable, under suitable conditions, of withstanding a tensile stress of 50 atmospheres. Dixon, using Berthelot's method, has concluded that the cohesive force of water per unit cross-section amounts to at least 150 atmospheres. The water used in his experiments was saturated with air and also contained pieces of the conducting tracts of plants. The measure-

[11] BERTHELOT, M. *Sur quelques phénomènes de dilatation forcée des liquides.* Ann. Chem. et de Phys., **30**: 250. 1850.

ments were made through a series of temperatures ranging from 25° to 80°C.

Renner[12] and Ursprung[13] working independently, have recently used the annulus cells of the spore cases of fern as a means of measuring the cohesion of water. Both investigators find that the cell contents of many of the spore cases may be brought into equilibrium (through the vapor phase) with solutions having an osmotic pressure of 300 atmospheres before the limit of cohesion is reached and air bubbles appear in the cells. All of these experiments appear to support the conclusion that the cohesion of water is amply sufficient to withstand the stresses in the stem of a tree.

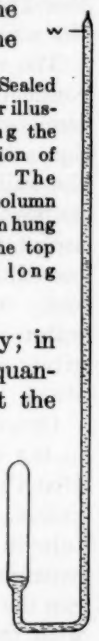

Fig. 6. Sealed tube for illustrating the cohesion of water. The water column is shown hung from the top of the long tube.

The cohesion of water may be easily demonstrated, as Dixon has shown, by means of a J-shaped sealed tube (fig. 6). A quantity of water more than sufficient to fill the lower limb is introduced into the tube, which is then partially exhausted and sealed off. It is unnecessary to reduce the air pressure below 2 cm. of mercury; in other words, the water may contain very appreciable quantities of air. If the tube is now first inclined so that the water fills the longer limb completely, which may be over a meter in length, and is then carefully raised to the position shown in figure 6, the water column remains hanging from the top of the tube. On destroying the cohesion of the column at some point by a sharp blow, or preferably by heating a stout platinum wire previously sealed through the wall of the tube for this purpose, the water column suddenly falls to the level determined by the gas pressure in the bulb.

Cohesion may also be readily demonstrated by a Bourdon spring connected with a bulb through a flexible capillary tube.

[12] RENNER, O. *Theoretische und Experimentalles zur Kohäsionstheorie der Wasserbewegung.* Jahrb. Wiss. Bot., **56**: 617–667. 1915.

[13] URSPRUNG, A. *Ueber die Kohäsion des Wassers in Farnannulus.* Ber. Deutsch. Bot. Gesells., **33**: 153–162. 1915.

The system is completely filled with alcohol at room temperature and sealed. The spring with its index is placed under a bell-jar, which is then evacuated. On cooling the bulb, the spring will close somewhat, due to the internal stress set up by the contracting liquid. This stress may be demonstrated by heating the capillary locally, thus breaking the liquid column, when the spring will be observed to fly back suddenly to the unstressed position. The stress exerted by the liquid at the time may be found by determining the external pressure necessary to produce the same distortion of the spring.

The channels in the stem of a tree through which water is conducted are divided into minute compartments by means of numerous longitudinal and transverse partitions. This configuration seems ill adapted to the conduction of fluids; for while the walls are permeable to water, they offer a great resistance to its flow. But from the standpoint of the cohesion theory of the ascent of sap this structure becomes, as Dixon[14] has shown, a beautiful adaptation of the plant to confer stability on the tensilely stressed transpiration stream. The ascending column of water, interlaced by these innumerable permeable partitions, is given great stability even though subjected to great tensile stress.

Observers agree that air bubbles are of common occurrence in the water ducts of the stems of plants. It is evident from Dixon's experiments that dissolved air is not prejudicial to cohesion. But if a minute bubble appears in an experimental tube in which the water is subjected to great stress the bubble expands rapidly and the column is at once ruptured. How then can the presence of air in the conducting channels be harmonized with the cohesion theory of the rise of sap? Here the plant again shows in the minute subdivisions of its conducting channels a beautiful provision against the interruption of its water supply through the development of bubbles in the stem. If an air bubble appears in one of the minute compartments, it may expand, as Dixon has pointed out, until it fills the compartment,

[14] DIXON, H. H. *Transpiration and the ascent of sap.* Progressus Rei Botanicae, **3**: 1–66. 1909.

but beyond that it can not go. As the air follows the water back into the imbibing walls minute capillary surfaces of great curvature are developed, which successfully withstand the pressure of the gas from within, and what is far greater, the stresses from without. This compartment then simply becomes inoperative. The transpiration stream flows around it, as the waters of a river flow around an island in its center.

When the world's supply of coal and oil is exhausted, man will be reduced to the extremity of dependence upon solar engines, water power, and wood as sources of energy, unless his ingenuity has meantime been equal to the task of liberating the energy of the atom. So far as we can see at present, wood and plant products will then constitute, as in fact they do now, the only means of storing in a readily transportable form the energy received from the sun. Hence, efficiency in plant production from the standpoint of both food and fuel promises to be a problem of rapidly increasing importance as the years progress—a problem which demands for its complete solution the fullest possible understanding of the physical and chemical processes associated with plant growth.

# PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

## THE PHILOSOPHICAL SOCIETY OF WASHINGTON

The 782nd meeting was held at the Cosmos Club, January 20, 1917. President BUCKINGHAM in the chair; 88 persons present. The minutes of the 781st meeting were read in abstract and approved.

The evening was devoted to hearing the address of the retiring President, Mr. LYMAN J. BRIGGS, on *The living plant as a physical system.* The address is published in this JOURNAL, **7**: 89–111. 1917.

DONALD H. SWEET, *Secretary.*

## THE CHEMICAL SOCIETY OF WASHINGTON

The 260th meeting of the society was held at the Cosmos Club, April 13, 1916. Dr. C. L. PARSONS, Secretary of the American Chemical Society, presented announcements in relation to the Spring Meeting of the society at Urbana, Ill. and the projected work of the Naval Advisory Board in its attempt to inventory the resources of the country. Dr. Parsons represents the Chemical Society in this work in the District of Columbia. The following program was presented:

H. W. DAUDT, Bureau of Chemistry: *Investigations of the Kjeldahl method of determining nitrogen.*

The proper conditions for the complete decomposition of refractory compounds of nitrogen with acid ammonium sulphate were discussed. Mercuric oxide cannot be replaced by other catalysts, or potassium sulphate by sodium sulphate. The results of analyses of compounds of various constitutions were discussed.

A new aeration apparatus is devised for this determination. Folin's method for determining ammonia is adapted to the Kjeldahl method. All the operation, including the measurement and addition of the sodium hydroxide, the passing of air through the resulting alkaline solution, and the absorption of the ammonia in standard acid solution, are carried on by means of air pressure or suction. The advantages over the more commonly used distillation method were discussed. (Author's abstract.)

J. M. JOHNSON, Bureau of Chemistry: *A fourth pentacetate of galactose.*

In continuation of the work on the preparation of the various isomeric acetates of the sugars, carried out in conjunction with Hudson, a fourth crystalline pentacetate of galactose, having properties quite distinct from those of the three known isomers, has been isolated. An account of the method of preparation and properties was presented.

E. A. HILL, Patent Office: *Van't Hoff's principle of optical superposition. The lactonic constitution of the aldose sugars and the melasaccharins and the constants from which their specific rotatory powers can be computed.*

By a comparison of the experimental values with the values of the specific rotation computed on the basis of certain assumptions as to constitution and structure, it is shown:

1. That in carbohydrates and their derivatives having a plurality of asymmetric carbon atoms, more particularly the aldose sugars (provided we assume the modern $\gamma$-oxidic or lactonic ring theory of their structure), the specific rotation $[a]_d$ is the algebraic sum of certain constants corresponding to such asymmetric atoms so that, if $A$, $\alpha$, $\beta$, $\gamma$, $\delta$, etc., be the constants for a given group of active isomers, the specific rotation will be given by the formula;

$$[a]_d = \pm A \pm \alpha \pm \beta \pm \gamma \pm \delta \ . \ . \ .$$

2. That Van't Hoff's so-called principle of optical superposition is therefore valid for these cases.

3. That the $\gamma$-oxidic or lactonic ring theory of these sugars, which has been used to explain the phenomenon of mutarotation, is thereby confirmed.

The agreement between observed and computed values is very satisfactory in each of the five groups presented. Thus, in both the aldopentose and aldohexose sugars the maximum difference does not exceed 1 per cent and the average difference is 0.1 per cent of the observed values.

The methods used for computing the constants are: 1st, a strictly algebraic method; 2nd, a method similar to that used by Dr. Hudson in computing his quantity $A$ and which is as follows: When the structural formulas of two active isomers differ only in the configuration of one and the same asymmetric atom, the algebraic difference of their specific rotations will be twice the value of the constant of such atom.

The 261st meeting of the Society was held in the Assembly Hall of the Y. M. C. A. Building, May 11, 1916. Amendments to the constitution were adopted abolishing the office of first and second vice-presidents, the present incumbents to become members of the Executive Committee, the membership of which was increased to six elected members. Mr. F. C. COOK was elected member of the Executive Committee to succeed H. M. LOOMIS, retiring from the section. The following resolution presented by a special committee consisting of J. A. LECLERC, J. T. KEISTER, and H. S. BAILEY was adopted:

In the death of Prof. GEORGE E. PATRICK the Chemical Society of Washington has lost one of its oldest members. Professor Patrick was ever a faithful attendant at its meetings and frequently took an active part in the discussions.

He was a man of broad discernment and of high ideals, brave, yet unobtrusive. One of his most noble deeds was the gift of several thousand dollars to The University of Kansas, a large part of the yearly proceeds of which is to be presented to the student preparing the best essay on Applied Christianity.

The Chemical Society of Washington records with sorrow the death of their fellow member and hereby places this meager testimony of his worth in its minutes.

The following program consisting of papers from the Hygienic Laboratory was presented:

C. N. MYERS: *The preparation of heavy metal salts of certain organic acids.*

An account of the methods of preparation and the properties of some of the less commonly known heavy metal salts of organic acids was given. These salts were prepared for use in such pharmacological investigations as are mentioned in the following abstract.

G. C. LAKE: *Some observations on the toxicity and chemotherapy of the heavy metals.*

This paper is a brief report on work done, under the direction of Prof. Voegtlin, with the lactates and thioglycollates of nearly all the heavy metals. Toxicity was determined on rats and guinea pigs by several routes of injection, the dosage being based on actual content of metal, and given in mgs. per kg. of body weight. The action and pathology were studied to some extent. It was found that all are relatively toxic provided they enter the circulation. There seems to be no constant relation between toxicity and atomic weight of the metal or its position in the periodic system. The preparations were all studied in relation to their action on *Tr. Brucei* in vitro and in vivo, using rats and guinea pigs. The only preparation giving any marked trypanocidal action was an antimonial. The great specificity of drugs in regard to their chemotherapeutic action is again emphasized by this work. (Author's abstract.).

ELIAS ELVOVE: *The separation and determination of small amounts of antimony.*

Small amounts of antimony (less than 1 mg.) can be estimated by comparing the color produced by treating the unknown solution with hydrogen sulphide water, with the colors similarly produced in solutions containing known amounts of antimony. As little as one-hundredth of a milligram of antimony in 20 cc. can be detected by means of the hydrogen sulphide test. The antimony sulphide resulting from amounts of antimony up to about 0.1 mg. in 25 cc. remains in colloidal solution for an hour or two and thus admits of its colorimetric estimation. In the presence of arsenic and tin (up to 5 mg.) the arsenic is first separated as ammonium magnesium arsenate by the aid of the simultaneous phosphate precipitation of Smith (Bur. Chem. Cir. No. 102). The filtrate is boiled down to about 10 cc., cooled, made up to 15 cc. with water acidified with 1 cc. concentrated hydrochloric acid (Sp. gr. 1. 19) and boiled for two minutes. After cooling, it is diluted again to 15 cc. with water further acidified by adding 5 cc. of

concentrated hydrochloric acid, and then mixed with 5 cc. of a saturated solution of hydrogen sulphide. This concentration of hydrochloric acid serves to keep the tin in solution but does not prevent the antimony from reacting with the hydrogen sulphide. The antimony standards are prepared simultaneously with the carrying out of the determination and are subjected to exactly the same treatment as the unknown. (Author's abstract.)

The 262nd meeting was held at the New National Museum as a joint meeting with the Washington Society of Engineers, May 24, 1916. The illustrated lecture of the evening was given by Mr. JOSEPH STEINMETZ, President of tht Aero Club of Pennsylvania, on *The machine shop and the chemical laboratory as related to national preparedness for defense.*

E. C. MCKELVY, *Secretary.*

## THE BOTANICAL SOCIETY OF WASHINGTON

The 114th regular meeting of the Society was held in the Assembly Hall of the Cosmos Club, Tuesday, October 3, 1916. Twenty-four members and six guests were present. The program consisted of the following papers:

*Dr. C. A. Davis, an appreciation.* DAVID WHITE: To be published elsewhere.

*R. M. Meade, an appreciation.* F. L. LEWTON:

Rowland Montgomery Meade, a most promising young botanist connected with the United States Department of Agriculture, died at San Antonio, Texas, June 25, 1916, a few weeks after his twenty-seventh birthday. He was born at Clyde, New York, May 16, 1889, graduated at the high school of his home town, and on the recommendation of Mr. O. F. Cook was appointed, March 15, 1905, as an assistant in experiments with boll-weevil resistant cotton. In 1907, as field agent, he accompanied Mr. Cook to Guatemala, to aid him in his studies of tropical species of cotton and his experiments with cotton insects. On July 1, 1908, after passing a civil service examination, he was appointed a Scientific Assistant in the Bureau of Plant Industry, and he continued his investigations in connection with the cotton plant in Texas, Arizona, and California. In December, 1908, he was elected to membership in the Botanical Society of Washington. On March 1, 1916, he was appointed superintendent of the experimental farm at San Antonio, Texas, under the office of Western Irrigation Agriculture. It was while performing his duties under this assignment that he was stricken with amoebic dysentery and died after an illness of ten days. He leaves a wife and an infant son. All those who came in contact with Roland Meade were attracted by his personal charm and sunny temperament and recognized his mental alertness, which gave promise for a bright future. His interest in growing plants was intense. He looked upon them as real living things,

and delighted to watch their morphological responses to changes of environment. He devised methods of describing and tabulating the minute differences of individual plants, as may be seen in his published papers. The following list of United States Department of Agriculture publications indicates the nature of his studies:

Supernumerary Carpels in Cotton Bolls. Bur. Pl. Ind. Circ. 111.

Methods of Securing Self-Pollination in Cotton. Bur. Pl. Ind. Circ. 121.

A Study of Diversity in Egyptian Cotton (joint author with O. F. Cook and A. McLachlan). Bur. Pl. Ind. Bull. 156.

Arrangement of Parts in the Cotton Plant. Bur. Pl. Ind. Bull. 222.

Single-Stalk Cotton Culture at San Antonio. Dept. Bull. 279.

Roland Meade's many friends in this Society and the Department of Agriculture will always remember him as a clean, lovable young man of great promise, who was cut off at the beginning of his life's work.

*Experiments in the use of peat in the greenhouse* (with lantern): H. C. THOMPSON.

Four years experimental work in growing greenhouse crops on muck soils shows that there is a greater difference in the productiveness of the various types than can be accounted for on the basis of fertilizing elements present. Three types of muck soil were used in the experiments. The type showing the smallest percentage of nitrogen and potash produced the largest yields of lettuce, cauliflower, and tomatoes. This was true of the pure muck plats as well as all plats containing muck and clay mixtures (mixtures 75 per cent muck and 25 per cent clay, to 12.5 per cent muck and 87.5 per cent clay). The difference in yields where the various types of mucks were used was probably due to the physical condition and to the organic life in the soil. In a field experiment the muck showing, on analysis, the highest nitrogen content gave the greatest increase in yield when manure was used. This increase from manure could not possibly be accounted for on the basis of plant food, as plats treated with large quantities of complete fertilizers showed a still greater increase when manure was applied. The manure was of special value in inoculating the soil with beneficial organisms. The muck producing the largest yield in the greenhouses showed no increase from the use of manure that could not be accounted for on the basis of plant food. It is interesting to note that the soil producing the largest yield in the greenhouse has been under cultivation much longer than the one producing the smaller yield.

The soil giving the best results produced good yields of lettuce, cauliflower, tomatoes, carnations, and roses. With the first two crops the pure muck plats produced the largest yields, while with tomatoes, carnations, and roses the mixture containing 50 per cent muck and 50 per cent clay produced the largest yields. All mixtures containing 50 per cent or more muck produced greater yields of lettuce, cauliflower, and tomatoes than a mixture containing 3 parts clay, 1 part sand, and

2 parts well rotted manure. In fact, 25 per cent muck practically equalled 33.5 per cent manure.

The speaker concludes that a good type of cultivated muck soil is valuable for greenhouse work and might be used to take the place of a part or all of the manure. However, it is doubtful if it would be practicable to use muck soil for greenhouse work except where it could be secured near at hand at a low cost.

*The origin and use of upland peat* (with lantern): FREDERICK V. COVILLE.

Upland peat, formed in thickets of laurel (*Kalmia latifolia*), was used experimentally in growing various species of plants. Among those successfully grown were a number of rare species seldom seen in cultivation and very difficult to propagate, including plants belonging to the Ericaceae, or heath family, which cannot be grown with success in ordinary soils. The list includes also several insectivorous plants and orchids.

Perhaps the most interesting and striking of all is an ornamental tree, *Franklinia alatamaha*, discovered in 1765 by Bartram and named in honor of Benjamin Franklin. It has beautiful white, sweet-scented flowers resembling those of a magnolia, but with one of the petals modified to a pouch-like form. This plant, originally from Georgia, is not now known to exist in the wild state. Closely allied to it but with evergreen instead of deciduous leaves is the *Gordonia lasianthus*, of the Southern States, sometimes known as black laurel or loblolly bay. Among our native orchids are the royal lady's slipper, *Cypripedium reginae*, and the pink-flowered *C. acaule*. A fit companion to them is an exquisite climbing lily-like plant sometimes called the empress lily (*Lapageria rosea*) with pendant flowers. This plant, discovered in the forest region of Chile, takes its generic name from that of the family of the Empress Josephine. Among insectivorous plants successfully grown are *Drosera rotundifolia* and other sundews; the curious Venus's flytrap (*Dionaea muscipula*); *Utricularia subulata* and *U. cleistogama* of sandy swamps and pine barrens. Other plants are *Cornus canadensis*, the dwarf dogwood or bunch berry; the fragrant twin-flower (*Linnaea borealis*); *Pinckneya pubens*, with flowers having inconspicuous petals but with a remarkable calyx of which one or two of the lobes are expanded into large conspicuous blades; and *Viola pedata*, the pansy violet of our rocky woods and sterile hills, with palmate leaves and velvety upper petals.

Among the Ericales are *Clethra alnifolia*, the sweet pepper bush of the Atlantic coast; *Dendrium prostratum*, the sand myrtle of the pine barrens; *Azalea vaseyi*, a remarkably beautiful pink-flowered species from the Appalachian region; *A. lutea*, with orange or yellow flowers; the common *A. nudiflora; A. viscosa*, with sweet-scented white flowers; and the cultivated Indian Azalea (*A. indica*). The list also includes *Rhododendron maximum*, the rose bay laurel; *R. carolinianum;* and *R. praecox*, an interesting early-blooming hybrid formed from *R. dahuricam* from the Lake Baikal district of Siberia and *R. ciliatum* of the

Himalayas; *Kalmia latifolia*, the mountain laurel; and *K. angustifolia*, commonly known as lamb kill or sheep laurel; *Leucothöe catesbaei*, with racemes of white flowers; *Eubotrys racemosa*, a coastal swamp plant; *Pieris floribunda*, an evergreen shrub of the Southern States; *P. japonica*, with long pendant racemes of white flowers; *Neopieris nitida; Epigaea repens*, the trailing arbutus or mayflower; *Gaultheria procumbens*, the aromatic wintergreen; and *Pernettya mucronata*, from the Magellan region. Among the heaths are *Calluna vulgaris*, the heather of Scotland; *Daboecia polifolia*, Irish heather; various species of heath from Europe and the Cape of Good Hope; *Gaylussacia dumosa*, the dwarf huckleberry; *G. frondosa*, the dangleberry; *G. ursina*, the bear huckleberry of the southern mountains; *Polycodium stamineum*, the squaw huckleberry or deer berry; *Vaccinium membranaceum; V. parvifolium*, the red fruited whortleberry of the northwest coast; *V. reticulatum*, the "ohelo" of Hawaii; *V. myrsinites*, the evergreen blueberry of Florida; *V. vacillans; V. corymbosum*, the high blueberry; *V. pallidum; V. hirsutum; V. erythrocarpum*, of the Allegheny Mountains; *V. vitis-idaea*, a circumpolar evergreen species; *V. canadense; V. angustifolium; V. nigrum; V. simulatum; V. atrococcum; V. ovatum*, of the Pacific coast; and *V. ciliatum*, the Japanese species. In addition to these species of Vaccinium there are also hybrids between several species. The list also includes *Oxycoccus macrocarpus*, the large American cranberry; *Arbutus unedo*, the Mediterranean madroño or strawberry tree; *A. canariensis*, with large edible fruit, from the Canary Islands; *A. arizonica*, from Arizona; and *A. menziesii* from the Pacific coast of North America.

The Rubiaceae are represented by the partridge berry, *Mitchella repens;* the Empetraceae by the circumpolar crowberry, *Empetrum nigrum;* and the Galacaceae by the well known evergreen *Galax aphylla* of our southern woods.

In addition to these may be mentioned a handsome gentian of the pine barrens, *Gentiana porphyria*, with flowers two inches in diameter; a dwarf fern, *Schizaea pusilla;* several species of Sphagnum, including *S. cymbifolium;* and two exotic plants with exquisitely fragrant flowers, *Daphne odora* from India, and *D. blagayana* from the Balkan region.

W. E. SAFFORD, *Corresponding Secretary.*

## THE BIOLOGICAL SOCIETY OF WASHINGTON

The 563rd meeting of the Biological Society of Washington was held at the Cosmos Club, Saturday, January 13, 1917; called to order by President HAY at 8 p.m. with 45 persons in attendance.

On recommendation of the council Dr. GEORGE W. FIELD, of the Biological Survey, was elected to membership.

President HAY announced as Committee on Publications: C. W. RICHMOND, J. H. RILEY, NED DEARBORN, W. L. MCATEE; and as Committee on Communications: WILLIAM PALMER, ALEX. WETMORE, R. E. COKER, L. O. HOWARD, A. S. HITCHCOCK.

Under the heading of Brief Notes, W. L. McATEE and ALEX. WETMORE called attention to the presence of white-winged crossbills in the vicinity of Washington, constituting the second authentic record of this species in the District fauna. The first specimen was seen by Mr. McAtee on December 10, 1916, in a flock of American crossbills. Later, on December 24, 27, and 30, other specimens were seen, as single birds and also in flocks, Mr. Wetmore having seen as many as forty birds together. In contrast to this unusual visit of a northern bird Mr. McAtee mentioned the lingering of summer birds, having noted a Cape May warbler on December 6, and a bluegray gnatcatcher about January 1. He mentioned also having found a box turtle out and active on January 7, 1917.

Mr. E. A. GOLDMAN mentioned the reported occurrence of Hudsonian chickadees in the vicinity of New York City and Boston.

Mr. A. S. HITCHCOCK called attention to the unusual precautions that were being taken in the care of the Linnaean Herbarium to protect it from damage by aircraft.

The regular program was as follows:

L. O. HOWARD: *Some European experiences with entomologists.*

Under this title Dr. Howard read three short papers, entitled "Rennes and René Oberthür," "An Entomological Trip to the Crimea," and "The Episode of Theophile Gautier," all illustrated with lantern slides. In the first he described the personality of René Oberthür, one of the great amateur collectors of insects in Europe, and his beautiful place at Rennes where he has a private museum, an extraordinary arboretum, and one of the largest collections of orchids in existence. He spoke at some length of the very important voluntary assistance which M. Oberthür had given the Bureau of Entomology in the collection and importation of the parasites of the gipsy moth and the brown-tailed moth from Europe into the United States, and gave an account of an automobile journey through Brittany and Normandy in the summer of 1909, on which he was accompanied by M. Oberthür and by Paul Marchal of the Station Entomologique de Paris.

In the second paper he described a journey from Budapest through Lemberg to Kiew in 1907; the establishment of an experimental station at Kiew under the direction of Prof. Waldemar Pospielow of the University of Kiew; the journey thence to Sebastopol, Bachtisserai, and Simferopol, the reginal museum at the latter place under the charge of Prof. Sigismond Mokchetsky; and the excellent work in economic entomology done by Professor Mokchetsky in the Crimea. He mentioned also the old palace of the Khan of the Crimea at Bachtisserai and the marine zoological laboratory at Sebastopol.

In the concluding episode he described his personal experiences in 1910 and 1912 with Theophile Gautier, one of the most successful rose growers of France, at Angers, a man of the simplest appearance and habits and of the highest standing in horticultural circles and an *Officier* of the order of *Mérite Agricole.*

H. C. OBERHOLSER: *Recent additions to the list of North American birds.*

Mr. Oberholser said that the period from 1910 to 1916 inclusive was one of great ornithological activity. During this period fully 125 species and subspecies were added to the list of birds known from North America. Most of these additions resulted from the description of new subspecies or the revival of hitherto unrecognized forms, which together amount to over 100, among the most interesting being five new subspecies from Newfoundland. Two distinct species were described from North America during this time: *Aestrelata cahow* from the Bermuda Islands, and a remarkable new gull, allied to *Larus californicus*, called *Larus thayeri*, from Ellesmere Land. Also a number of extralimital forms were for the first time detected within our boundaries, among the most notable of which might be mentioned *Puffinus carneipes* taken in California; *Totanus totanus* from Greenland; *Calliope calliope camtschatkensis* and *Hypocentor rusticus*, both from Kiska Island, Alaska; *Nyroca ferina*, *Marila fuligula*, *Clangula clangula clangula*, *Cryptoglaux funerea funerea*, *Coccothaustes coccothaustes japonicus*, and *Fringilla montifringilla*, all from the Pribilof Islands; *Poecilonetta bahamensis* from Florida; *Petrochelidon fulva pallida* from Texas; and *Tyrannus melancholicus satrapa* from Maine.

WILLIAM PALMER: *The fossil seacow of Maryland.*

Mr. Palmer exhibited the fifth thoracic neural arch of a sirenian which was shown to be unlike that of the manatee and to agree absolutely, except in size, with a similar bone of Steller's seacow (Hydrodamalis) from Bering Sea. The specimen was found, freshly fallen, under a cliff of the Calvert Miocene on the western shore of Maryland. It was suggested that the species was living during the period following the first erosion of the Cretaceous and the deposition of the Eocene, as all the specimens so far found in the Miocene were clearly redeposits from an earlier age.

M. W. LYON, JR., *Recording Secretary.*